DERWENT-ACC-NO: 2000-664790
DERWENT-WEEK: 200159

TITLE: Detection of X-rays for obtaining improved radiographic images is by orienting a radiation detector by a selection of acute angle between a direction of incident radiation and a side of the detector

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PATENT-ASSIGNEE: MAMEA IMAGING AB[MAMEN]

PRIORITY-DATA: 1999SE-0000856 (March 10, 1999)

PATENT-FAMILY:

PUB-NO	PUB-DATE	LANGUAGE	PAGES	MAIN-IPC
WO 200054072 A1	September 14, 2000	E	017	G01T 001/24
AU 200036897 A	September 28, 2000	N/A	000	G01T 001/24
SE 9900856 A	November 10, 2000	N/A	000	G01T 001/24

DESIGNATED-STATES: AE AL AM AT AU AZ BA BB BG BR BY CA CH CN CR CU CZ DE DK DM E
E ES FI GB GD GE GH GM HR HU ID IL IN IS JP KE KG KP KR KZ LC LK LR LS LT LU LV
MA MD MG MK MN MW MX NO NZ PL PT RO RU SD SE SG SI SK SL TJ TM TR TT TZ UA UG US
UZ VN YU ZA ZW AT BE CH CY DE DK EA ES FI FR GB GH GM GR IE IT KE LS LU MC MW N
L OA PT SD SE SL SZ TZ UG ZW

APPLICATION-DATA:

PUB-NO	APPL-DESCRIPTOR	APPL-NO	APPL-DATE
WO 200054072 A1	N/A	2000WO-SE00488	March 10, 2000
AU 200036897 A	Based on	WO 200054072	N/A
AU 200036897 A	N/A	1999SE-0000856	March 10, 2000

March 10, 1999
SE 9900856A

INT-CL_(IPC): G01T001/24; H01L031/115

ABSTRACTED-PUB-NO: WO 200054072A
BASIC-ABSTRACT: NOVELTY - X-rays for obtaining improved radiographic images are
detected by orienting a semiconductor radiation detector comprising a selection
of an acute angle between a direction of incident radiation and a side of the
detector having the height so that the incident radiation mainly hits the side
of the radiation detector.

DETAILED DESCRIPTION - Detection of X-rays for obtaining improved radiographic
images includes a step of orienting a semiconductor radiation detector (101)
whose height is greater than its thickness. The orienting step comprises a
selection of an acute angle between a direction of incident radiation and a
side of the detector having the height so that the incident radiation mainly
hits the side (100) of the radiation detector. The hit area excludes
section(s) between the edge(s) of the detector and active sensor area(s) and
that all of the energy of the radiation is dissipated within the detection.
INDEPENDENT CLAIMS are also included for (A) an apparatus for detection of
incident radiation for radiographic imaging comprising x-ray detector having
individual pixel sensors (103), electrical outputs for each of the sensors, and
electrical connections between each of the pixel sensors so that the output
corresponding to corresponding points in each sensor is combined; and (B) use
of an apparatus for detection of incident radiation in scanned-slot medical
imaging used in mammography, bone densiometry, or non-destructive testing.

USE - For detecting X-ray for obtaining improved radiographic images.

ADVANTAGE - The invention enables a detection quantum efficiencies (DQE) close to 100% for energies of interest in diagnostic X-ray imaging which is 10-50 keV, combined with a high spatial resolution. It is very simple and inexpensive to implement in a detector. It also improves the X-ray image and/or lowers the radiation dose for the patient. The detector depth can be made large without having the X-ray passing the dead area close to the edge.

DESCRIPTION OF DRAWING(S) - The figure shows a top view of the detector chip.

Side 100

Semiconductor radiation detector 101

Guard ring 102

Pixel sensor 103

CHOSEN-DRAWING: Dwg.1/2

TITLE-TERMS:
DETECT RAY OBTAIN IMPROVE RADIOGRAPHIC IMAGE ORIENT RADIATE DETECT SELECT ACUTE ANGLE DIRECTION INCIDENT RADIATE SIDE DETECT

DERWENT-CLASS: K08 S03 S05 U12 U13

CPI-CODES: K08-E; K09-E;

EPI-CODES: S03-E06B3; S03-E06H5; S03-G02B2G; S05-D02A5; U12-A03; U13-A01A;
U13-A01X;

UNLINKED-DERWENT-REGISTRY-NUMBERS: 1496S; 1666S

SECONDARY-ACC-NO:
CPI Secondary Accession Numbers: C2000-201275
Non-CPI Secondary Accession Numbers: N2000-492729

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G01T 1/24, H01L 31/115 — A1

(11) International Publication Number: WO 00/54072

(43) International Publication Date: 14 September 2000 (14.09.00)

(21) International Application Number: PCT/SE00/00488

(22) International Filing Date: 10 March 2000 (10.03.00)

(30) Priority Data:
9900856-7 10 March 1999 (10.03.99) SE

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(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published

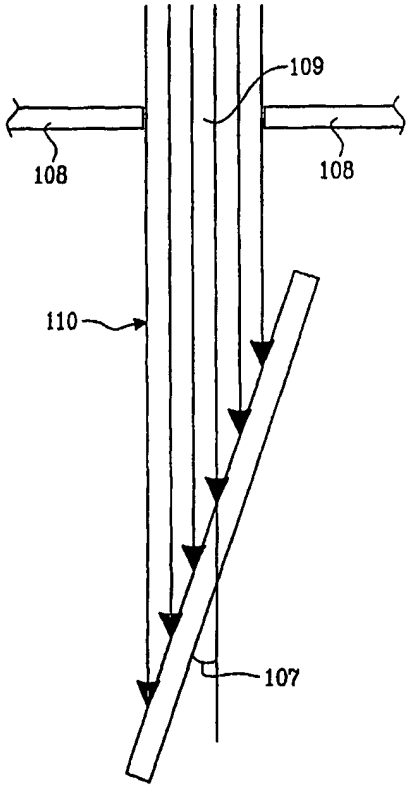
With international search report.

Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: METHOD AND APPARATUS FOR DETECTING X-RAYS AND USE OF SUCH AN APPARATUS

(57) Abstract

The present invention relates to a method of detecting x-rays for obtaining improved radiographic images including a step of orienting a semiconductor radiation detector (101) whose height is greater than its thickness. The orienting step comprises a selection of an acute angle (107) between a direction of incident radiation and a side of said detector having said height such that said incident radiation (110) mainly hit the side (100; 105) of said radiation detector (101). The hit area excludes at least a section between at least one edge of said detector and at least an active sensor area and that substantially all of the energy of the radiation is dissipated within the detector.



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EE	Estonia	LR	Liberia	SG	Singapore		

Title

METHOD AND APPARATUS FOR DETECTING X-RAYS AND USE OF SUCH AN APPARATUS

Technical field

The present invention relates to a method for detecting x-rays as described in the preamble of claim 1. The invention also relates to an apparatus as described in the preamble of claim 5 and a use of such apparatus as described in the preamble of claim 16.

Background to the invention

In medical x-ray imaging the central problem is to achieve the best possible image at the lowest possible radiation dose. To achieve this, high detection efficiency for all x-ray photons passing through the patient is crucial. Current x-ray imaging systems work with Detection Quantum Efficiencies (DQE) ranging from 10% to around 60%.

Silicon is in many ways the ideal detector material. The main advantages are the high quality and purity of the crystal combined with very low cost as a result of research and development in the semiconductor industry and the large volumes of silicon used in this field.

The main disadvantage with silicon is its low atomic number and corresponding decrease in stopping power for higher energy x-rays. A silicon detector wafer can only be made with a maximum thickness of around 1mm, and the standard thickness is about half of that. Thicker detectors will need application of prohibitively high voltages to deplete the whole detector volume to become an efficient x-ray detector. If the x-rays are incident at right angle to the surface this correspond to an efficiency of only 25% at 20keV.

A way around this problem is to orient the detector edge-on to the incident beam. In this geometry, the thickness of the silicon stopping the x-rays could be large enough to stop virtually all incident x-rays. This method is outlined in the invention described in US patent 4,937,453 by Robert S. Nelson. Edge-on detectors for increased efficiency is also conceivable for other semiconductor detectors but is particular important in the case of silicon because of the limited stopping power for this material due to its lightness.

A problem not anticipated in the method and device described in Nelson's patent (US 4,937,453) is that the semiconductor detector is always mechanically damaged in a zone close to the edge when it is cut. The cutting is usually performed with a diamond saw or a laser. In this area a large amount of background current is generated and the active sensors in the semiconductor wafer has to be put some distance from the edge in order not to be saturated by this background current, which would mask the signal from the x-rays. Usually, but not always, one or several guard-rings are placed between the active sensors (at least one sensor) and (at least one of) the edge(s) to sink the current generated at the edge of the detector and thus preventing it from reaching the active sensors. The distance between the edge and the active sensors are from 0.1mm to 0.6mm and the x-rays stopping in this region will not be detected. This, so called dead area, is equivalent to an inefficiency of the order of 20% in diagnostic x-ray imaging, such as mammography.

The loss of information is even more serious since predominantly the low energy photons that carry the most contrast information to the image will stop in the region close to the edge, which is not an active detector volume, and mainly the high energy photons, with less contrast information, will penetrate further down into the detector.

According to DE 19 61 84 65, a detector array has a number of detectors, each provided by a semiconductor plate of a directly converging semiconductor material with an electrode layer on two opposing sides. At least two detectors lie adjacent one another vertical to a surface receiving the incident radiation, with the main surfaces of the detectors set at an angle of between zero and 90 degrees to the latter surface. Separators of a radiation absorbing material are inserted between

the detectors. The fundamental idea is to extend the length of the path of the incident radiation to the semiconductor detectors without increasing the distance between the electrodes. Moreover, the detector arrangement is intended for high energy radiation and is provided to detect Compton radiation.

JP 50732150 provides an arrangement to reduce manufacturing cost and improve SN, measurement precision, and using performance. An X-ray inspecting device is equipped with an X-ray source for irradiating X rays onto a sample in revolution, a collimator having slits formed in radial form, in order to draw the X-ray which permeate the sample is arranged; and a semiconductor detector for detecting the X-rays by a sensing part through the radiation of the X-ray beam from the slit is provided. Since the X-ray inspection device is installed in the angle other than a nearly right angle for the plane parallel to the vertical direction revolution axis center of the semiconductor inspection part and the sample and installed in inclination in an incidence angle for the extension line of the X-ray beam, the irradiation of the scattered X-ray due to the sample into the semiconductor detector is prevented, and the X-ray beam supplied from the slit can be surely irradiated on the whole surface or a part of the sensing part. Also this arrangement is for high radiation applications.

Summary of the invention

The object with the present invention is to provide a method for detecting x-rays which solves the above mentioned problems by providing a method according to claim 1.

Another object of the invention is to provide an apparatus for detecting x-rays according to claim 5 and a use of said apparatus according to claim 16.

An advantage with the present invention is that it enables a DQE close to 100% for energies of interest in diagnostic x-ray imaging ranging from 10keV to 50keV, combined with a high spatial resolution.

Another advantage is that the present invention is very simple and inexpensive to implement in a detector.

Another advantage is that the detector depth can be made large without having the x-rays passing the dead area close to the edge.

Another advantage is that the present invention improve the x-ray image and/or lower the radiation dose for the patient.

Brief description of drawings

Fig.1 shows the detector chip in perspective looking from the top. A guard ring is indicated together with the strips for the top contact for the individual diodes. The bond pads for each strip for connections to electronics are not indicated.

Fig. 2 shows the detector looking from the side together with incoming x-rays and a collimator defining the shape of the x-ray beam.

Detailed description of the preferred embodiments

A silicon detector is fabricated from a raw silicon wafer that is exposed to different treatments to get the desired resistivity and other material parameters and the pattern of silicon strip sensors defining the individual pixels in the detector is fabricated through standard photolithographic techniques.

In Fig. 1 a detector chip 101 is displayed in a perspective view and a guard ring 102 is indicated together with individual pixel sensors 103 on a front side of the detector. The size of the pixel sensors is mainly determined by the demands on spatial resolution for a certain imaging task. In applications like mammography the distance between two adjacent pixels should be of the order 25 μm to 100 μm. The dead area 104 corresponds approximately to the distance from the edge of

the detector to somewhere in between where the guard ring and where the strips start. The thickness of the wafers normally range from 300 μm to 500 μm. To deplete the whole volume of the detector a bias voltage is applied between the back of the detector 105, that is usually entirely covered with aluminum. The depletion can for example be achieved with +80V connected to the backside of the detector wafer. The pixel sensors can then be at ground and connected to electronics. In this case the holes created by the incident x-rays are collected by the electronics. With an inverse diode structure for the sensor pixels and -80V connected to the back of the detector the electrons would be collected by the electronics and this would work equally well. The bias voltage necessary to deplete the whole wafer is very dependent on the individual detector type and thickness and ranges from 10V to over 1000V.

The electronics, usually in terms of Application Specific Integrated Circuits, to collect and process the signals from the individual sensor pixels will be connected to the individual sensor pixels through standard interconnection techniques like wire bonding or bump bonding. The pads usually necessary for these interconnections are not indicated in Fig. 1 but should be situated close to the end 106 of the strips.

This invention suggest a geometry between the incident x-rays and the detector such that the inefficiency mentioned above disappears. Fig. 2 shows a detector that is slightly tilted with respect to the incident x-rays in order to make them hitting the detector at a small angle to the detector surface.

To achieve maximum detection efficiency, e.g. for mammography, the detector should be oriented relative to the incident x-rays according to Fig. 2. with a certain angle 107 between the detector surface and the x-rays. The collimator 108 will shape the x-ray beam to match the detector area (active area). By changing the angle of the incident x-rays relative to the surface of the detector the thickness of silicon that the x-ray will encounter is determined. The detection efficiency in turn is determined by the thickness of the silicon and the detection efficiency can thus be selected to meet requirements for a particular imaging task. If we assume a wafer

thickness of 0.3mm and an x-ray energy of 25keV that is typical for mammography we will, with an angle of 2.8 degrees, achieve a detection efficiency in silicon exceeding 90 %. In this case, if the collimator slot 109 defining the shape of the incident x-rays has a width of 50 μm this would require an overall length of the detector of around 10mm. The incident x-rays will encounter around 7.5mm of silicon. A larger angle would mean slightly decreased detection efficiency but a shorter detector. Moreover, the dead are is excluded for the radiation.

For a 0.5mm detector thickness the same performance will be achieved with a slightly larger angle, around 3.8 degrees. Also fairly large angles of around 10 degrees results in as much as around 3mm depth of silicon for any incident x-rays in this case. This yields an efficiency that is high enough for several applications at lower energies, for 20 keV it would exceed 85%.

If the collimator is wider, e.g. 100 μm, the detector will have to be made longer in order to cover all the area under the collimator slot 109.

There is a choice weather to have the front side of the detector 101 in Fig. 1 or the back side of the detector 105 in Fig. 1 to face the incoming x-rays. Any of those schemes would work quite well but it is slightly advantageous to have the backside of the detector facing the x-rays. The reason for this is that the depletion zone, i.e. the active detector volume, does not extend all the way to the edge of the detector also in this direction, even if the dead area is much smaller, approximately of the order 1 μm, compared to the edge-on case. Since the extension of this dead area is less thick on the back side since less processing of the detector has taken place here it is advantageous to have the x-rays incident to the back side of the detector since this would yield a slightly increased efficiency.

In a system the x-ray imaging object will be placed between two collimator slots which are aligned with respect to each other and look more or less identical. The first collimator will shape the x-ray beam to match the active detector area. The second collimator slot will remove Compton scattered x-rays and the detector will be positioned after this collimator slot.

One important extension of the scheme above is to put several collimator slots and corresponding detectors after each other. This would increase image acquisition time since the area where x-rays are detected is increased. In Fig. 2 this would correspond to putting similar detectors and slots to the left and/or right of the indicated slot and detector. It may also be advisable to put an x-ray absorbing metal plate in between different detectors in this scheme to prevent scattered x-rays to reach adjacent detectors.

Other semiconductors than silicon, such as e.g. Gallium Arsenide or CdZnTe could be used in the scheme above instead of Silicon. They are however more expensive and difficult to work with and parameters like charge collection efficiency for the charge induced by the x-rays are not as good as for Silicon.

The invention is not limited the shown embodiments but can be varied in a number of ways without departing from the scope of the appended claims and the arrangement and the method can be implemented in various ways depending on application, functional units, needs and requirements etc.

CLAIMS

1. A method of detecting x-rays for obtaining improved radiographic images including a step of orienting a semiconductor radiation detector (101) whose height is greater than its thickness, **characterised by** said orienting step comprises a selection of an acute angle (107) between a direction of incident radiation and a side of said detector having said height such that said incident radiation (110) mainly hit the side (100; 105) of said radiation detector (101), said hit area excluding at least one section between at least one edge of said detector and at least one active sensor area and that substantially all of the energy of the radiation is dissipated within the detector.

2. A method according to claim 1 **characterised by** said angle (107) is selected to be less than 10 degrees.

3. A method according to claim 1 or 2 **characterised by** said method further comprises the step of collimating using a collimator (108) with a collimator slot (109) to prevent the incident radiation (110) to hit the edge the detector (101).

4. A method according to claims 1 - 3, **characterised by** that said detector is arranged in an x-ray imaging ranging from about 10keV to 50keV.

5. An apparatus for detection of incident radiation for radiographic imaging comprising:

- x-ray detector means (101) comprising a plurality of semiconductor x-ray strip detectors (103), said detector means being of sufficient height to cause the dissipation of substantially all of the incident radiation within said detector means,
- electrical outputs for each of the strip detectors, and
- electrical connections between each of the semiconductor x-ray strip detectors such that the output corresponding to corresponding points in each of the detectors is combined,

characterised in that said x-ray detector means (101) is oriented relative to the incident

radiation (110) such that an acute angle (107) is selected between a direction of said incident radiation and a side of said detector having said height such that said incident radiation mainly hit the side (100; 105) of said detector means (101), that the area exposed to the incident radiation excludes at least one section of said detector between at least one edge of said detector and at least one active sensor area and that substantially all of the energy from the incident radiation is dissipated within the detector.

6. An apparatus according to claim 5, **characterised in that** said detector means have a guard ring (102) to sink leak current.

7. An apparatus according to claim 5 or 6, **characterised in that** said thickness of the detector means is between 0.1mm and 1.0mm.

8. An apparatus according to any of claims 5-7, **characterised in that** said apparatus further comprises a collimator (108) with a collimator slot (109) to prevent the incident radiation (110) to hit the edge the detector (101).

9. An apparatus according to claim 8, **characterised in that** said apparatus comprises several detector means, each having a collimator slot (109), placed side by side.

10. An apparatus according to claim 9, **characterised in that** an absorber is placed between said detector means (101) to prevent scatter from one detector means to another.

11. An apparatus according to any of claims 4-9, **characterised in that** said detector means are made of silicon.

12. An apparatus according to any of claims 5-10, **characterised in that** said detector means are made of Gallium Arsenide or CdZnTe.

13. An apparatus according to any of claims 5-12, **characterised in that** said angle (107) is less than 10 degrees.

14. An apparatus according to any of claims 5-13, **characterised in that** said incident radiation (110) hits the backside (105) of the detector means (101).

15. An apparatus according to any of claims 5-14, **characterised in that** said apparatus ranges from about 10keV to 50keV.

16. Use of an apparatus for detection of incident radiation in scanned-slot medical imaging, **characterised by** using an apparatus according to any of claims 8-15.

17. Use of an apparatus for detection of incident radiation in scanned-slot medical imaging according to claim 16, **characterised by** said medical imaging is used in mammography, bone densitometry or non-destructive testing.

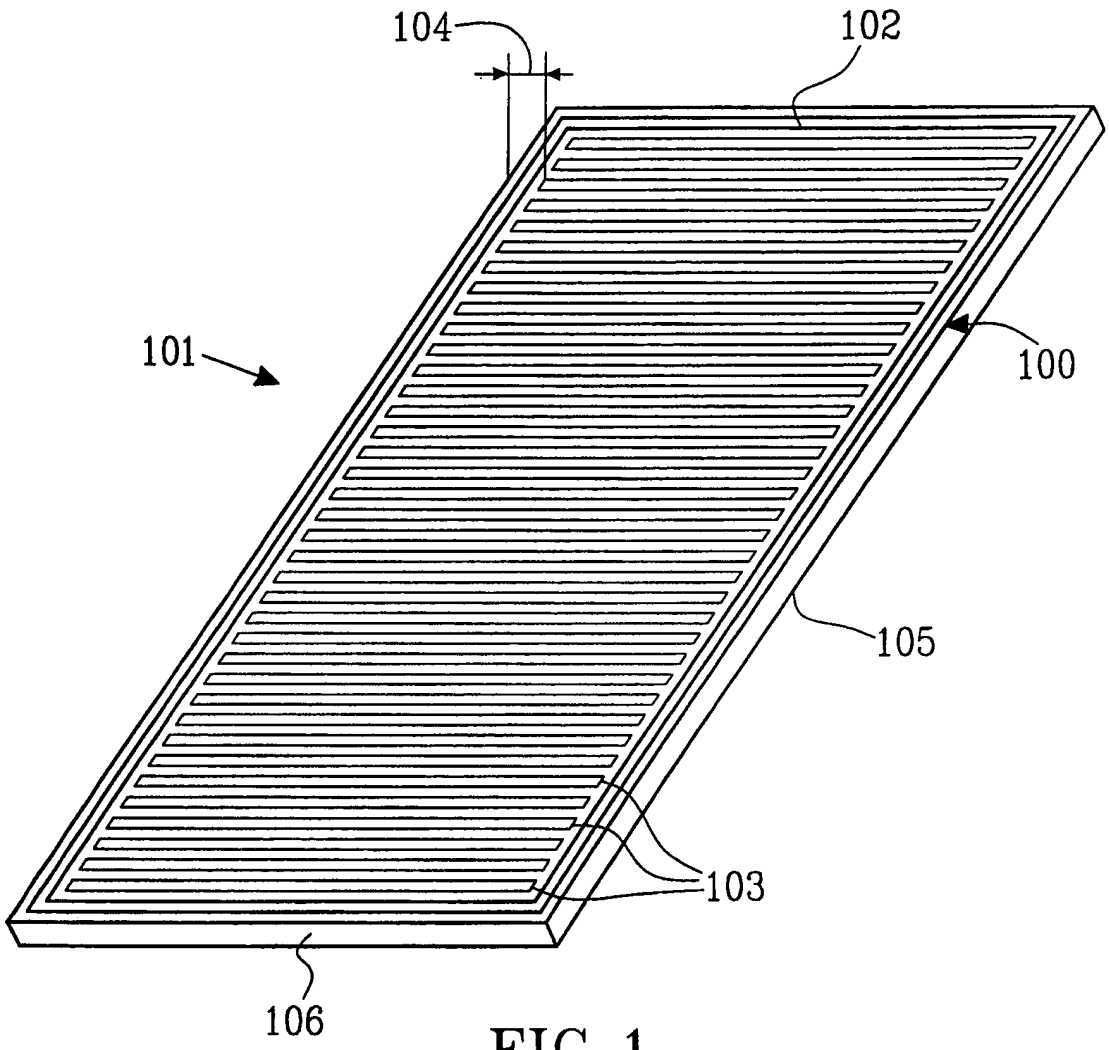

FIG.1

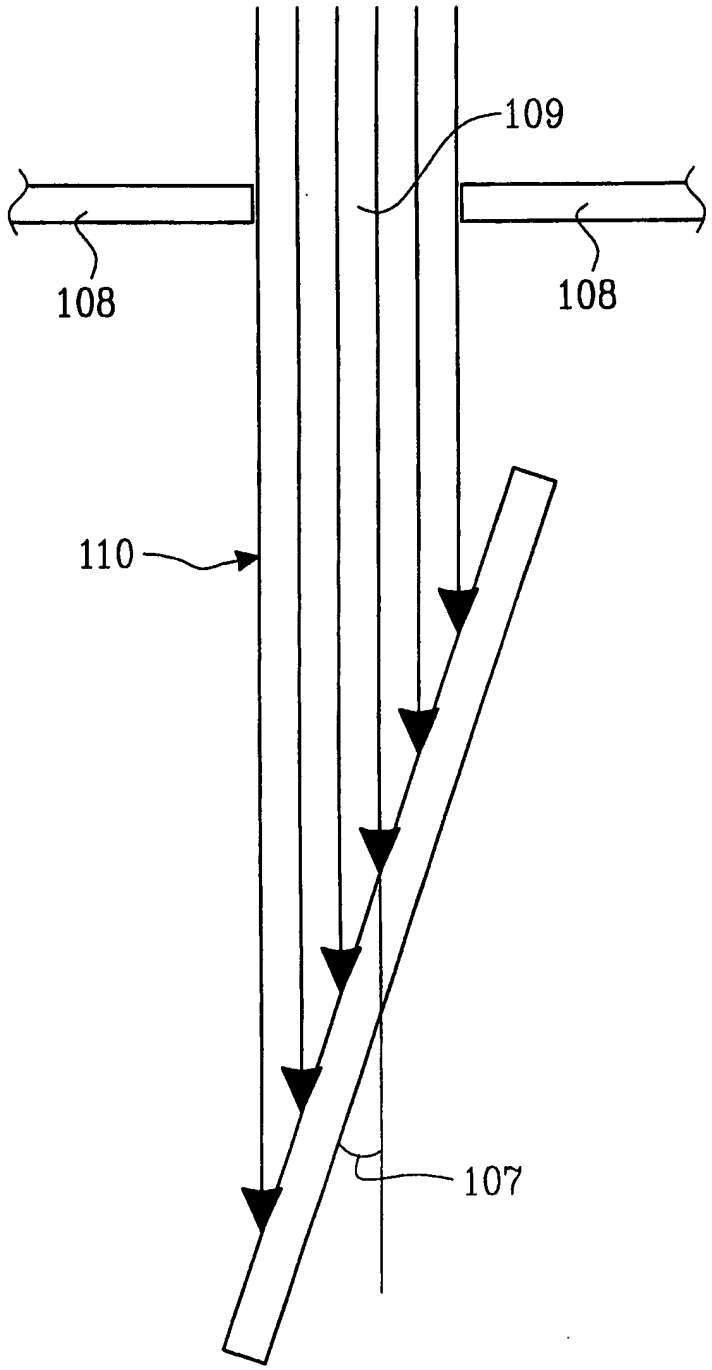

FIG.2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/00488

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G01T 1/24, H01L 31/115
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G01T, H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 19618465 C1 (SIEMENS AG), 5 June 1997 (05.06.97), column 2, line 39 - line 61; column 3, line 34 - line 35, figures --	1-17
Y	JP 63117286 (MATSUSHITA ELECTRIC IND CO LTD) 1998-09-30 (abstract), (online) (retrieved on 2000-06-30). Retrieved from:EPO PAJ Database; figure, abstract --	1-17
Y	US 5847398 A (SHAHAR ET AL), 8 December 1998 (08.12.98), column 6, line 26 - line 56, figures --	1-3,8-9

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
3 July 2000	17 -07- 2000
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/00488

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5227635 A (IWANCZYK), 13 July 1993 (13.07.93), figure 1, abstract ---	1-2,6
Y	JP 5072150 A (HITACHI LTD) 1993-03-23 (abstract) World Patents Index (online). London, U.K.: Derwent Publications, Ltd. (retrieved on 2000-06-30). Retrieved from: EPO WPI Database. DW199316,Accession No. 1993-131747, & JP 5072150 (HITACHI LTD) 1993-07-26 (abstract), (online) (retrieved on 2000-06-30). Retrieved from: EPO PAJ Database; & JP 5-72150 (HITACHI LDT) 23 March 1993 ---	1-2,5,13
Y	US 4937453 A (NELSON), 26 June 1990 (26.06.90), column 3, line 56 - column 4, line 26, figure 1 ---	5-17
Y	JP 59099384 (SHIMAZU SEISAKUSHO KK) 1984-10-02 (abstract), (online) (retrieved on 2000-06-30). Retrieved from: EPO PAJ Databse; figures 1-5, abstract --- --------	1,5

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
PCT/SE 00/00488

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 5847398 A	08/12/98	NONE	
US 5227635 A	13/07/93	AU 3075292 A	15/06/93
		MX 9206704 A	30/06/94
		WO 9310471 A	27/05/93
US 4937453 A	26/06/90	US 5017782 A	21/05/91

Form PCT/ISA 210 (patent family annex) (July 1992)

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G21K 1/02 — A1

(11) International Publication Number: WO 00/60610

(43) International Publication Date: 12 October 2000 (12.10.00)

(21) International Application Number: PCT/SE00/00642

(22) International Filing Date: 3 April 2000 (03.04.00)

(30) Priority Data:

9901230-4	1 April 1999 (01.04.99)	SE
60/154,092	15 September 1999 (15.09.99)	US

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(81) Designated States: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published

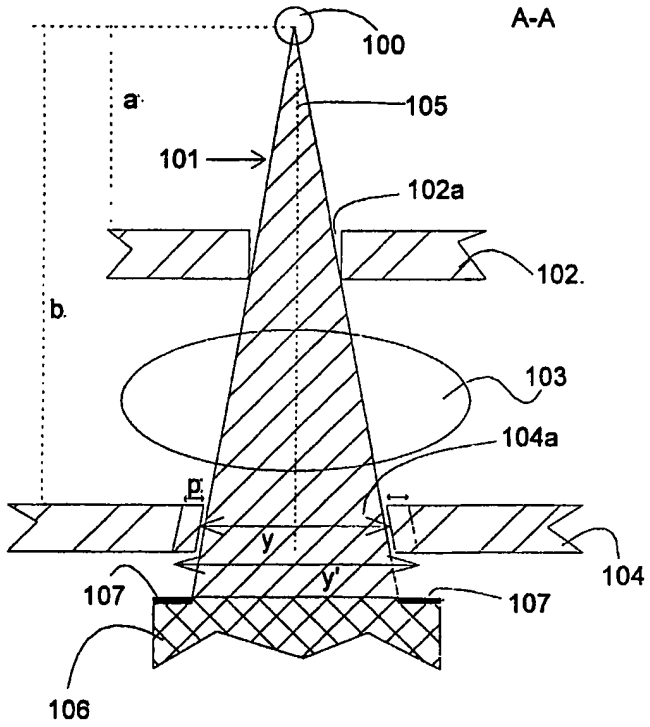
With international search report.

Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: METHOD AND APPARATUS FOR SIMPLIFIED ALIGNMENT IN X-RAY IMAGING

(57) Abstract

The invention relates to a method and an apparatus for simplified alignment in scanned slot x-ray imaging. The apparatus has a first collimator (102) and a second collimator (104) arranged in a first distance (a) and a second distance (b), respectively, from a radiation source (100). Each collimator is provided with a slot (102a, 104a) and a detector (106) is located under the second collimator slot, said slot of said second collimator being wider than the said slot of said first collimator and said detector under the second slot is wider than the first collimator slot and the second collimator slot. The slot (104a) of said second collimator has a width (y') not less than a safety margin and the product of the width (x) of the slot (102a) of said first collimator (102) and said second distance (b) divided with the said first distance (a) for allowing a misalignment with respect to a central symmetry line (105) of said slots (102a, 104a).



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Title

METHOD AND APPARATUS FOR SIMPLIFIED ALIGNMENT IN X-RAY IMAGING

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a scanned-slot x-ray imaging system, having a first collimator and a second collimator arranged in a first distance and a second distance, respectively, from a radiation source and each provided with a slot and a detector located under the second collimator slot, said slot of said second collimator being wider than the said slot of said first collimator and said detector under the second slot is wider than the first collimator slot and the second collimator slot.

BACKGROUND OF THE INVENTION

The common systems for x-ray imaging consist of an x-ray source and an area detector placed behind the object to register the image. The main drawback with this set-up is its sensitivity to background noise in form of Compton scattered radiation. Existing methods to remove this background noise are inefficient and also remove a fraction of the primary x-rays that contain the image information. This result in a dose increases exceeding a factor 2 or more.

One way around this problem is a scanned-slot set up. A pre-collimator slot before the object shapes the x-ray beam to match the active detector area. The slot is moved mechanically to image the entire object. It is also possible to have the object moving with respect to the slot, this is however usually more inconvenient because the object is usually heavier than the mechanics for the slot. Since only a narrow fan-beam is crossing the object at any single time and the area of the secondary collimator is small relative to the area of the captured image, the amount of Compton scattered x-rays is minimized. Another advantage with the scanned-slot approach is that the required detector area is much smaller, this cuts cost and also enables the use of more expensive and efficient detector materials if desired.

A drawback with the scanned-slot geometry is that only a small fraction of the x-rays from the source is actually used to form the image. As a result, the time for image acquisition is extended and the x-ray tube need to be turned on for a longer period of time. A way of mitigating this problem and achieve a practical system is to use a multi slot collimator with different detector arrays under each slot. This however makes the image acquisition non-trivial since the information from the different detectors has to be sewn together into one image without any visible artifacts such as boarder lines between areas where different detectors were used.

One of the most important constraints for medical x-ray imaging systems is to avoid any exposure of the patient to x-rays in areas where there is no active detector to register the x-rays. This would only lead to an unnecessary dose increase. In a multi slot set-up alignment is crucial since the detectors need to cover the full area under each slot.

International patent application no. WO 82/01124 describes an apparatus including a planar, proximity type x-ray image intensifier for detecting a fan beam of x-rays and for producing an intensified output visible light image on an output display screen which is sensed by a scannable, linear array of solid state diode detectors. In a first embodiment, a pair of side by side arrays are utilized to eliminate the effects of flare in the display screen. One of the linear arrays looks at the line signal on the output screen and the second linear array looks at a location on the output screen which is adjacent and parallel to the line signal. A net signal is derived by subtracting the signals from adjacent elements of the two parallel arrays so that signal flare in the image intensifier tube is removed. In a second embodiment, display screen flare is eliminated by covering the vacuum side of the display screen with metal having a thickness sufficient to dissipate one third of the kinetic energy of photo-electrons passing through it.

US 4,649,559 discloses a large area, digital radiography apparatus in which a prescatter and a postscatter collimator are moved simultaneously with an x-ray image intensifier tube whose output display is scanned by a stationary scanning camera to produce a digitized x-ray image over a large cross-sectional area of the patient.

It is important to have the detectors covering the whole x-ray-imaging object in the direction orthogonal to the scan without any gaps in between detectors. For semiconductor detectors this is an engineering challenge since there is always a dead-area close to the edge at the detector. This is caused by mechanical damage when cutting the detectors on the wafer, and usually a guard-ring has to be placed between the edge and the active detector area to sink leak current emanating from the mechanical damages. Ideally none of this dead area should be exposed to the diagnostic x-rays.

SUMMERY OF THE INVENTION

One object of the present invention is to provide a set-up for multi-slot medical x-ray imaging, which greatly simplifies the alignment and also presents a method for tiling different semiconductor detectors to cover the whole slot without introducing any dead area in between detectors.

Another object of the present invention is to allow for a misalignment with respect to the central symmetry line with less than a safety factor so that no primary radiation is lost in the post collimator.

These objects are obtained through arranging the initially mentioned slot of said second collimator with a width not less than a safety margin and the product of the width of the slot of said first collimator and said second distance divided with the said first distance for allowing a misalignment with respect to a central symmetry line of said slots.

Furthermore, the system can comprise plurality first and second collimators and detectors arranged side by side to enable a multi slot scan.

In a preferred embodiment said detector is a semiconductor detector and it can be oriented such that an edge of faces said incident x-rays. However, the detector can be a film-screen combination, a CCD coupled to a scintillator through optical fibre bundles, or a gas detector.

If the detector is a gaseous detector, it can have a drift field to drift the electrons released through interactions with the x-rays to the edge of the detector where the signal is amplified and registered.

The invention also concerns, in a scanned-slot x-ray imaging system, having a first collimator and a second collimator arranged in a first distance and a second distance, respectively, from a radiation source and each provided with a slot and a detector located under the second collimator slot, said slot of said second collimator being wider than the said slot of said first collimator and said detector under the second slot is wider than the first collimator slot and the second collimator slot, a method for allowing a misalignment with respect to a central symmetry line of said slots. The method comprises arranging said slot of said second collimator such that the width of it is not less than a safety margin and the product of the width of the slot of said first collimator and said second distance divided with the said first distance. Moreover, the collimators can be so arranged that a dead area on said detector is not exposed to said x-ray.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the invention will be described with reference to non-limiting drawings, illustrating a preferred embodiment, in which

Fig. 1 is a schematic cross-sectional view of an embodiment according to the invention,

Fig. 2 is the embodiment according to fig. 1, provided with distance signs, and

Fig. 3 is a schematic top view of a system with a plurality of first collimator slots.

DESCRIPTION OF A PREFERRED EMBODIMENT

A preferred embodiment of a set-up for scanned-slot x-ray imaging is displayed in Figure 1.

It comprises a first collimator 102 provided with a first slot 102a, and a second collimator 104 provided with a second slot 104a. The collimators are spaced apart to provide a space in which an object 103, to be examined, is positioned. Beneath the second collimator 104 a detector 106 is located. A source 100 of X-rays 101 is also provided.

The x-rays 101 incident on the set-up is shaped by the first collimator 102 to hit the detector 106. The purpose of the second collimator 104 is to absorb Compton scattered x rays from the object 103.

Ideally the collimators 102 and 104 and the detector 106 should be symmetrical with respect to the centerline 105. If the slots are equal in width and also the detector bas this width any misalignment in terms of deviations from the symmetry line 105 for one of the slots or the detector will result in a loss in efficiency. To avoid this problem, the second collimator slot 104 is slightly wider compared to the first collimator slot 102. Moreover, the width of the detector 106 is larger than the collimator slot 102 but also larger than the collimator 104. All this is indicated slightly exaggerated in Fig. 1. By means of this set-up the system is insensitive to small misalignments with respect to the symmetry line 105 and manufacturing cost can be decreased and reliability improved.

Fig. 2 shows the principle of the invention. It is assumed that the distance between the source 100, first collimator 102 and the second collimator 104 is *a* and *b*, respectively, the width of the slot of first collimator 102 *x* and the width of the slot of the second collimator 104 *y*. Taking into the account the magnification due to the divergent x-ray beam and the principle of the similar triangles, then

$$\frac{a}{x}=\frac{b}{y} \quad or \quad \frac{x}{a}=\frac{y}{b} \quad \Rightarrow \quad y=\frac{xb}{a}.$$

What is needed is a wider second collimator such that y + 2p = y' > y, i.e xb/a +2p > y, where p is a safety margin and y' is the desired width. Therefore, it is possible to allow for a misalignment with respect to the central symmetry line with less than p and still not loose any primary radiation in the second collimator 2. The same reasoning is applicable to the width of the detector.

The factor p depends on the stability of the actual beam and corresponds to the probability of the misalignment. The range of p may be between 0-200 μm. The distance p should be chosen such that any increase in radiation dose due to misalignment should be less than about 5% of the total radiation dose given to the patient. The probability for misalignment has to be assessed through repetitive measurements under realistic operating conditions for the x-ray imaging set-up. The los factor for primary radiation may be 1%.

Moreover, the dead area 107 caused by mechanical damage when cutting the detectors on the wafer, and usually provide with a guard-ring placed between the edge and the active detector area to sink leak current emanating from the mechanical damages is so covered by the collimator 104 so that it is

not exposed to the x-rays.

The collimators are preferably made from efficient absorbers as for example W, Cu or Fe. The detector could be a silicon strip detector, a CCD (Charge Coupled Device) camera coupled to a scintillating screen or a gaseous avalanche detector such as for example a parallel plate chamber. In the case of the CCD camera coupled to the scintillating screen this coupling could be provided through for example optical fibre bundles.

In case of a silicon strip detectors the wafers can be made at least 500 μm thick without problems and the signals are registered by standard state of the art electronics. When the detector is a semiconductor detector it can advantageously be oriented edge-on to the incident x-rays. With edge-on is meant that the x-rays incite one edge of the of the detector, which also can be tilted slightly. Another option would be to provide a detector in the form of a film screen combination.

A gas-detector with the gas volume oriented edge-on can be made to any desired thickness by introducing a drift volume where the electrons created through interaction with the gas molecules can be collected through an electric drift field and drifted towards the edge of the detector where avalanche multiplication can take place and the signal registered by state of the art electronics.

In Fig. 3, a top view of a system with a plurality of first collimator slots is displayed. Each of the lines 201 indicates one slot; i.e. a hole cut in the metal with a width equivalent to the desired width of the x-ray beam after passing the collimator. As shown there is a plurality of collimators in two dimensions. Figs. 1 and 2 correspond to a cross-section along line A-A in Fig. 3 for any of the slots 201 indicated in Fig. 3.

The invention is not limited the shown embodiments but can be varied in a number of ways without departing from the scope of the appended claims and the arrangement and the method can be implemented in various ways depending on application, functional units, needs and requirements etc.

CLAIMS

1. A scanned-slot x-ray imaging system, having a first collimator (102) and a second collimator (104) arranged in a first distance (a) and a second distance (b), respectively, from a radiation source (100) and each provided with a slot (102a, 104a) and a detector (106) located under the second collimator slot, said slot of said second collimator being wider than the said slot of said first collimator and said detector under the second slot is wider than the first collimator slot and the second collimator slot, *characterised in,*
that said slot (104a) of said second collimator has a width (y') not less than a safety margin and the product of the width (x) of the slot (102a) of said first collimator (102) and said second distance (b) divided with the said first distance (a) for allowing a misalignment with respect to a central symmetry line (105) of said slots (102a, 104a).

2. The system as claimed in claim 1,
characterised in,
that it comprises plurality first and second collimators and detectors arranged side by side to enable a multi slot scan.

3. The system as claimed in claim 1 or 2,
characterised in,
that said detector is a semiconductor detector

4. The system as claimed in claim 3,
characterised in,
that said detector the detector is a semiconductor detector oriented such that an edge of faces said incident x-rays

5. The system as claimed in claim 1 or 2,
characterised in,
that said detector is a film-screen combination

6. The system as claimed in claim 1 or 2,
characterized in,
that said detector is a CCD coupled to a scintillator through optical fibre bundles

7. The system as claimed in claim 1 or 2,
characterized in,
that said detector is a gas detector

8. The system as claimed in claim 7,
characterised in,
that said detector is a gaseous detector with a drift field to drift the electrons released through interactions with the x-rays to the edge of the detector where the signal is amplified and registered.

9. The system as claimed in any of preceding claims,
characterised in,
that the safety margin is so chosen that any increase in radiation dose due to misalignment is less than about 5% of the total radiation dose.

10. In a scanned-slot x-ray imaging system, having a first collimator (102) and a second collimator (104) arranged in a first distance (a) and a second distance (b), respectively, from a radiation source (100) and each provided with a slot (102a, 104a) and a detector (106) located under the second collimator slot, said slot of said second collimator being wider than the said slot of said first collimator and said detector under the second slot is wider than the first collimator slot and the second collimator slot, a method for allowing a misalignment with respect to a central symmetry line (105) of said slots (102a, 104a),
characterised by,
arranging said slot (104a) of said second collimator such that the width (y') of it is not less than a safety margin and the product of the width (x) of the slot (102a) of said first collimator (102) and said second distance (b) divided with the said first distance (a).

11. The method of claim 10,

characterised in,

that the collimators are so arranged that a dead area (107) on said detector is not exposed to said x-ray.

12. The method of claim 10,

characterised in,

that the safety margin is so chosen that any increase in radiation dose due to misalignment is less than about 5% of the total radiation dose.

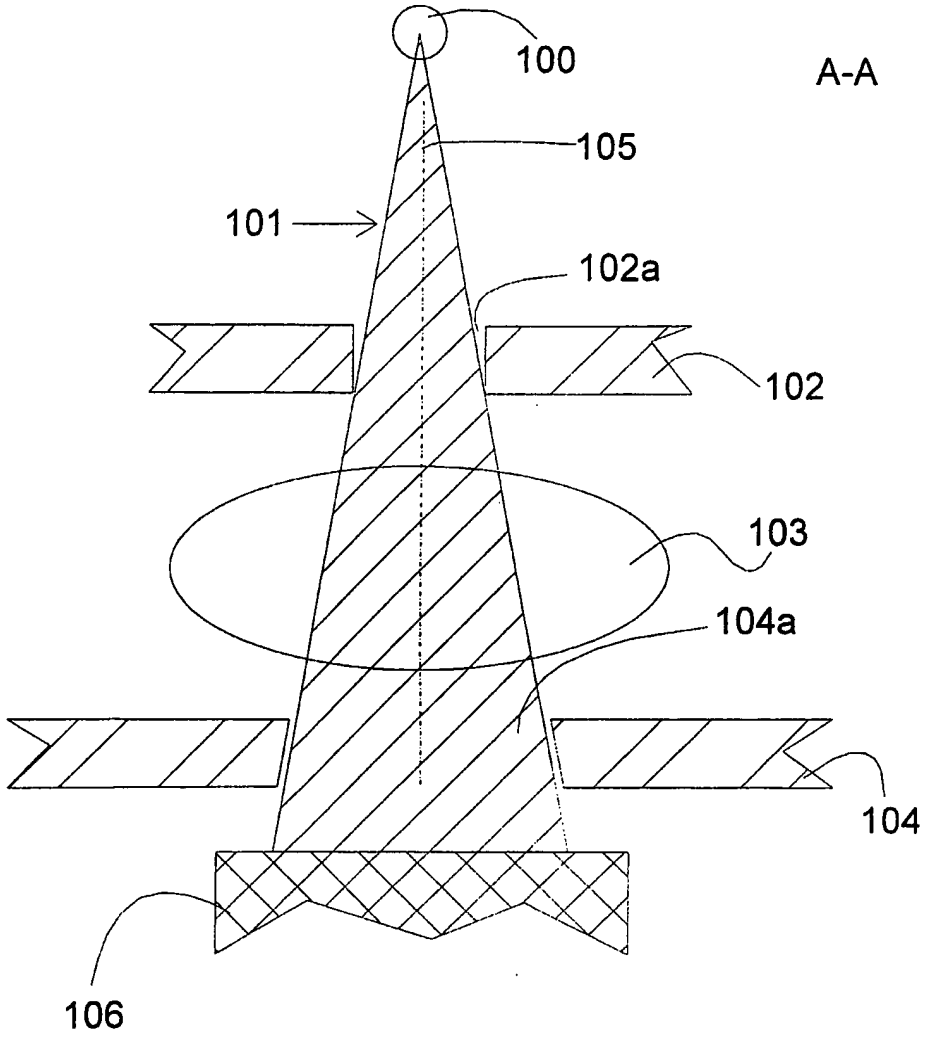

Fig. 1

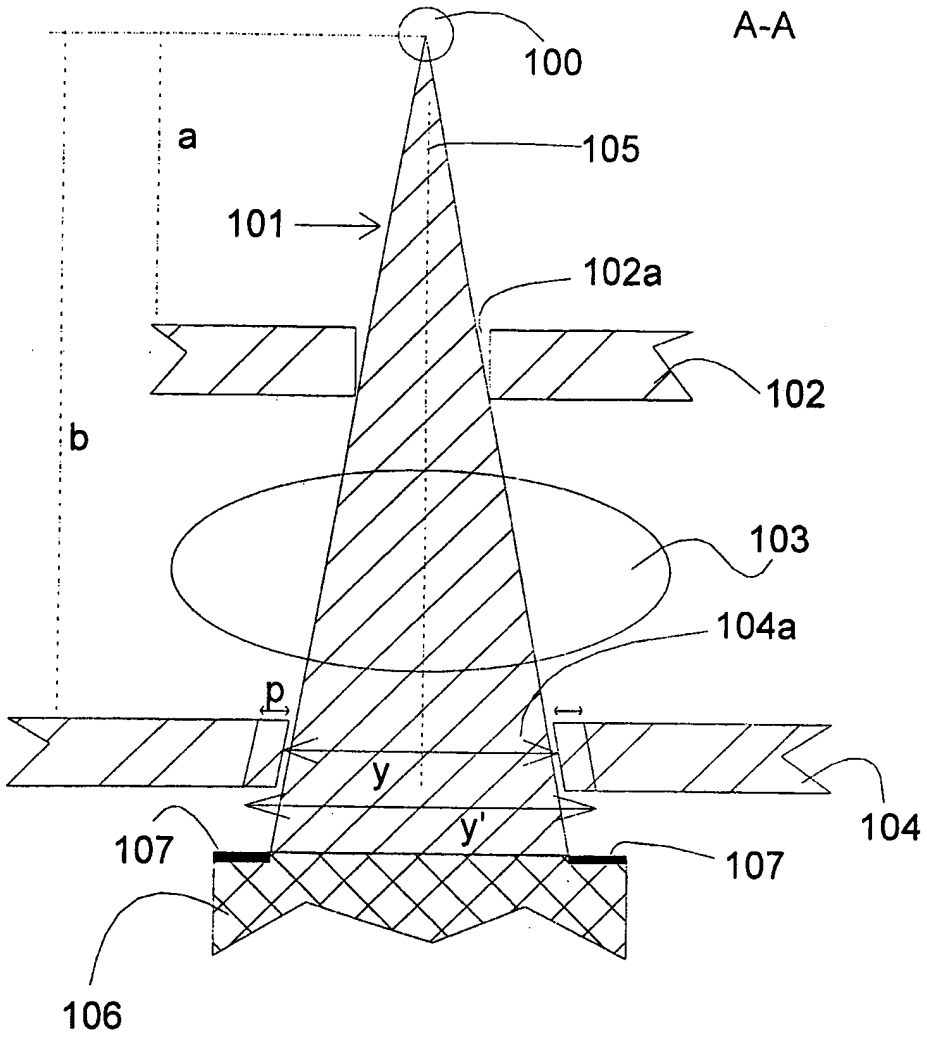

Fig. 2

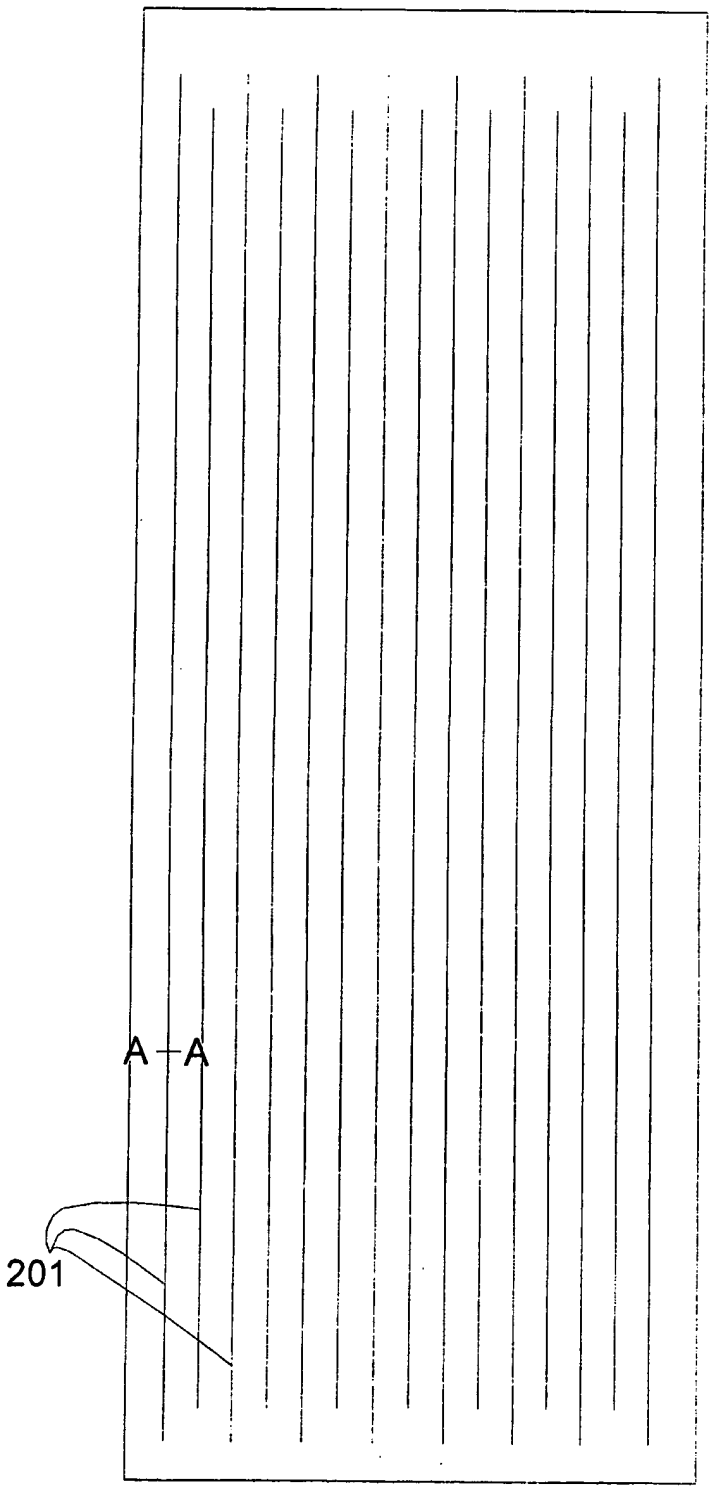

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/00642

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G21K 1/02
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G21K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 2753119 A1 (PALOMEX OY), 22 June 1978 (22.06.78), see the whole document	1,3-12
Y	--	2
Y	WO 8201124 A1 (DIAGNOSTIC INFORMATION, INC.), 15 April 1982 (15.04.82), page 3, line 33 - page 8, line 17	2
	--	
X	US 4649559 A (SHIH-PING WANG), 10 March 1987 (10.03.87), figure 1, abstract	1,3-12
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☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Cilla Lyckman/AE Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
PCT/SE 00/00642

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 4649559 A	10/03/87	EP 0140695 A	08/05/85
		JP 60174137 A	07/09/85

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 July 2001 (26.07.2001)

PCT

(10) International Publication Number
WO 01/54137 A1

(51) International Patent Classification[7]: G21K 1/04

(21) International Application Number: PCT/SE01/00139

(22) International Filing Date: 24 January 2001 (24.01.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

0000228-7	24 January 2000 (24.01.2000)	SE
60/195,359	24 January 2000 (24.01.2000)	US

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(81) Designated States *(national)*: AE, AG, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

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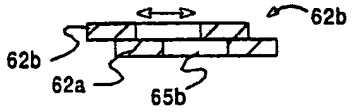
WO 01/54137 A1

(54) Title: METHOD AND ARRANGEMENT FOR VARIABLE EXPOSURE OF X-RAY DETECTOR



(57) Abstract: The present invention relates to a method and arrangement in an x-ray imaging apparatus (10), comprising at least one x-ray source (11), a collimator (42, 52, 62a, 62b, 72) and a registering means (43, 73), the arrangement is arranged for providing a variable exposure of said registering means (43, 73) to x-ray radiation from said x-ray source (10) through slots (45, 55, 65a, 65b, 75) on said collimator (42, 52, 62a, 62b, 72). Said arrangement comprises at least one of said collimator (42, 52, 62a, 62b, 72) or registering means (43, 73), which are arranged moveable relative each other to vary number of x-rays registered by said registering means.

TITLE

Method and arrangement for variable exposure of x-ray detector

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a method and arrangement for varying the exposed surface of an x-ray detection/registering means. The x-ray imaging apparatus comprises at least one x-ray source, a collimator having slots and a registering means.

BACKGROUND OF THE INVENTION

When analysing an object, specially a tissue or a part of human body, through x-ray radiation, the result of the analyse depends highly on the number of x-rays passing through the object and registered by means of a detector or film. The thickness and density of different objects are some parameters that effect the passage of the x-rays. In for example mammography examination the x-ray apparatus must be adjusted for different patients having different bodily characteristics.

In case of an x-ray detector, one important parameter is the radiated area, i.e., the surface of the detector, which is exposed to the x-rays. Yet another important parameter is the time of exposure, which in case of living tissues is critical, as the radiation dose corresponding to a long exposure time for x-ray radiation may endanger the tissue by inducing cancer.

Semiconductor based x-ray detectors are known, e.g. through Swedish Patent Application No. 9801677-7, Danielsson. According to this document an edge-on detector is placed tilted with respect to the incident x-rays.

According to the pending Swedish patent application no. 9903559-4, an arrangement for detecting x-ray radiations is provided comprising a carrying member on one face arranged with detectors consisting of a plurality of sensors arranged on a substrate. The detectors are arranged substantially edge to edge at least in one row on at least one side of said carrying member.

Patent no. US 4937453, describes an apparatus for detecting x-ray radiation in a radiographic imaging context is disclosed. It is particularly useful in conjunction with slot and slot scan radiography. In accordance with this invention, detectors are constructed and arranged such that substantially all of the energy from an x-ray to be detected is discharged in the detector. In this way a detector is provided which provides a direct electronic read out, high x-ray stopping power and high spatial resolution while obtaining good signal collection efficiency without the use of excessively high voltage levels. In the preferred embodiment, solid-state x-ray detectors are constructed such that the thickness of the detector along the direction of incident X-rays is long enough that substantially all of the x-ray energy is discharged in the detector. The detector is arranged edge on, with its longitudinal axis substantially parallel to the incident x-ray.

Also, gas-based detectors are known. WO 99/23859, for example concerns an apparatus for radiography, and especially for planar beam radiography, and also a detector for detecting incident radiation. The detector according to this invention, which detects incident radiation, is a gaseous parallel plate avalanche chamber, including electrode arrangements between which a voltage is applied for creating an electrical field, which causes electron-ion avalanches of primary and secondary ionization electrons released by incident radiation. The detector is oriented, in relation to the incident radiation, so that the radiation enters sideways between a first and a second parallel plate, between which the electrical field is created. Electrical signals induced by said electron-ion avalanches are detected in at least one detector electrode arrangement, including a plurality of detector electrode elements arranged adjacent to each other, each along a direction being essentially parallel to the incident radiation.

US 4,953,189 discloses a method and device for producing flux equalized x-ray images for medical radiography through the use of a scanning fan shaped x-ray beam and a feedback control system which regulates the beam intensity at a multiple number of points along the fan beam to compensate for the x-ray attenuation variations of the patient.

According to US 5,136,672, at least one primary diaphragm comprises two elements displaceable so as to form a linear fan-shaped beam, which is incident on an object to be examined. The elements form the slit-shaped aperture forming the fan beam in their normal X-

ray beam forming position and are moveable to a respective, selectable limit position perpendicularly to the fan shaped beam in order to define and mark an examination zone greater in cross-section area than the fan beam with a light beam. Light incident on the examination zone is restricted by the diaphragm elements in their limit positions, thus marking the examination zone with the light beam. X-ray exposure of the object to be examined takes place only when the elements are between the two positions defining the examination zone of the primary diaphragm where its diaphragm elements occupy in their respective limit positions.

SUMMARY OF THE INVENTION

The main object of the present invention is to provide a method and arrangement, which enable varying the number of detected x-rays, preferably depending on the features of the object to be examined.

Preferably, the invention is applicable in the applications using scanned slot set-up.

Another object of the invention is to adjust the spatial resolution to comply with the diagnostic requirements for the moment by varying the slot width.

Therefore the initially mentioned collimator arrangement comprises at least two substantially similar collimator parts having similar slot configurations arranged on top of each other and that said substantially similar collimator parts are arranged displaceable relative each other. According to one preferred embodiment, the slots of each collimator part are arranged displaced relative each other along a longitudinal axis of the collimator.

According to another embodiment said slots of each collimator part are arranged along a longitudinal axis of the collimator.

The registering means can be one of a semiconductor-based detector, a gas-based detector or an x-ray sensitive film.

In an x-ray imaging apparatus comprising at least one x-ray source, a collimator arrangement

and a registering means, the collimator arrangement being provided for varying an exposure areas of said registering means to x-ray radiation from said x-ray source, the invention relates to a method for providing said variable exposure of said registering means. The method comprises providing said collimator arrangement with at least two substantially similar collimator parts having similar slot configurations and arranging said parts on top of each other displaceable relative each other.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the invention will be further described in a non-limiting way under reference to the accompanying drawings, in which:

Fig. 1	is a schematic side view of a known x-ray imaging apparatus,
Figs. 2a and 2b	are lateral views of two different multi-slot collimators according to prior art,
Fig. 3	is a schematic and exaggerated cross-sectional view of a (multi-slot) collimator and a detector assembly according to fig. 1,
Fig. 4	is a schematic and exaggerated cross-sectional view of a collimator and a detector assembly according to the invention,
Fig. 5	is a top view of a collimator according to the invention,
Fig. 6	is a cross-sectional view of a collimator according to figs. 4 and 5, and
Fig. 7	is a schematic and exaggerated cross-sectional view of a collimator.

DETAILED DESCRIPTION OF THE EMBODIMENTS

In x-ray imaging the number of detected x-rays determines the image acquisition time yielding an acceptable image quality. In a scanned slot set up it is thus possible to adjust the required image acquisition time by changing the width of the slots and thus the number of x-ray hitting the object and the detector. Note that the detector needs to be wider than the largest slot used in order to detect all incident x-rays. In scanned slot x-ray imaging the spatial resolution in the dimension orthogonal to the slot is determined by the slot width. By varying the slot width it is possible to adjust the spatial resolution to comply with the diagnostic requirements for the

moment.

For the invention essential parts of an x-ray imaging apparatus 10 according to known techniques are illustrated in fig. 1. Other parts present in the apparatus, obvious for a skilled person, but not important for the invention are not shown for simplicity reasons. The simplified x-ray imaging apparatus comprises a radiation source 11, a collimator 12 and a detector assembly 13. An object 14 to be examined is located between the collimator 12 and the detector assembly 13.

The collimator is made of an x-ray blocking material and is arranged to expose a determined part of the detector for x-rays through slots 15. Two different types of collimators are illustrated in figs. 2a and 2b. The collimator 22a of fig. 2a is provided with slots 25a arranged in two rows and displaced relative each other along the longitudinal axis of the collimator. The collimator 22b of fig. 2b is provided with an oblong slot 25b, which can be divided into smaller slots through partition walls 26b. The form and arrangement of the slots are described in more detail in prior art as disclosed above. The collimator may comprise a 30 line slots or 30 plus 30 half lines. The slots and corresponding detectors may in some cases also be cut with an angle different from 90 degrees with respect to the scanning motion.

Fig. 3 illustrates a schematic collimator-detector assembly, in which a collimator 32 having slots 35 is arranged to expose a predetermined part of the detector 33 to the x-ray radiation (indicated with arrows). The surface section of the detector 33 exposed to the radiation is indicated with a thicker line.

According to the invention, the objective of the invention is obtained by varying the exposed surface of the detector to the x-rays, it is the projection of the slot(s) on the detector.

An embodiment according to the invention is illustrated in figs. 4, 5 and 6. According to the embodiment of fig. 4, a collimator 42 comprises at least two relative each other displaceable parts 42a and 42b, which provide slots 45 with variable width. The parts are arranged in different planes. A first position of the collimator sections providing a maximal slot width is indicated with dashed lines. A minimal slot width (=0 mm) is obtained when no slot are placed

in front of each other. It is also possible to arrange both parts laterally displaceable relative each other.

Fig. 5 is a top view of a collimator 52 comprising a first part 52a and a second part 52b arranged movable relative each other, e.g. through insertion of one part into the other one. Hence, the width of each slot 55 is variable. One position of the collimator parts providing a wide slot width is illustrated with dashed lines and a second position, in which the slot width is narrow is illustrated with solid line. The displacement of the collimator parts may be achieved by means of a step-motor (not shown) or the like by providing one or both of the parts with, e.g. teeth/wheel, belt or the like. The step motor may be controlled by means of a computer unit, e.g. with respect to the objects' density and/or thickness.

In fig.6, the collimator 52, comprises two substantially similar collimators, a first (stationary) part 52a with a fixed slot 55a width, and a second movable part 52b having a slots 55b similar to the first part, arranged to be displaced on one side of the first part to cover the slots 55a and change the slot-width. By arranging collimators on top of each other one can adjust the slot width for all slots by one single movement of collimators relative to each other in the dimension orthogonal to the slots.

Although, the examples show collimators with slots displaced relative a longitudinal axis of the collimator, it is however possible to use the same technique for collimators having slots along a longitudinal axis of the collimator.

The mechanical displacement of the second part can be accomplished using a step-motor (not shown) or the like, e.g. by providing the second part with teeth/wheel, belt or the like, or piezoelectric actuators. The motor/actuator may be controlled by means of a computer unit, e.g., with respect to the objects' density and/or thickness.

Moreover, the invention also allows providing collimators with high precession. Slots are very small recesses in a carrier, each slot having a width of for example 50 μm, which is difficult to produce depending on the manufacturing process and material. However, it is possible to produce collimators with 150 μm slots and arrange them according to the provisions of the

invention to achieve smaller slot widths. It is especially useful in case of complex slot configurations. Thus, the invention provides means for producing high precession collimators.

Fig. 7 is a further embodiment. The collimator 72 is arranged rotatable along a longitudinal axis 77 (anywhere along the short side of the substantially rectangular shaped collimator). According to this embodiment, the variation of exposed area is achieved by rotating the collimator 72 so that the slot 75 is positioned in an angle α, then if assuming the width of the slot is b and the width of a section exposed through the slot is a, then the variation of a: Δa is obtained through $\Delta a = b \,.\, cos\, \Delta\alpha$ (for $\alpha = 0$, $a = b$). Consequently, the width of the section c, exposed to the radiation, on the tilted detector 73, tilted in an angle β is: $c = a / cos\, \beta$ and accordingly the variation of c: $\Delta c = b \,.\, cos\, \Delta\alpha / cos\, \beta$. A first position of the collimator 72 is shown with dashed line and a second rotated position with the solid line.

The mechanical rotation can be accomplished using a step-motor (not shown) or the like through providing the second part with, e.g. teeth/wheel, belt or the like or piezoelectric actuators (not shown). The motor/actuator may be controlled by means of a computer unit, e.g. with respect to the objects' density and/or thickness.

It is also possible to provide both the detector and the collimator rotatable. Consequently, the collimator can be both rotatable and comprise of parts for varying the slots.

The detector may be any of detectors mentioned in the background part of the present specification and do not need to be tilted as shown in the various embodiments.

The invention is not limited to the shown embodiments and can be varied in a number of ways without departing from the scope of the appended claims and the arrangement and the method can be implemented in various ways depending on application, functional units, needs and requirements etc. In one embodiment it is possible to rotate the tilted detector to change the tilting angle with respect to the slot. Instead of detectors it is also possible to use a film, known per se, in which case additional collimators should be arranged after the object to be examined. It is also possible to stack more than two collimator parts.

CLAIMS

1. A collimator arrangement (42, 52) in an x-ray imaging apparatus (10) comprising at least one x-ray source (11) and a registering means (43), said collimator arrangement being provided for varying an exposure areas of said registering means (43) to x-ray radiation from said x-ray source (10),
characterised in
that said collimator arrangement comprises at least two substantially similar collimator parts (42a, 52a; 42b, 52b) having similar slot configurations arranged on top of each other and that said substantially similar collimator parts are arranged displaceable relative each other.

2. The collimator arrangement of claim 1,
characterised in,
that said slots of each collimator part are arranged displaced relative each other along a longitudinal axis of the collimator.

3. The collimator arrangement of claim 1,
characterised in,
that said slots of each collimator part are arranged along a longitudinal axis of the collimator.

4. The arrangement according to any of preceding claims,
characterised in,
that said registering means is one of a semiconductor-based detector, a gas-based detector or an x-ray sensitive film.

5. In an x-ray imaging apparatus (10) comprising at least one x-ray source (11), a collimator arrangement and a registering means (43), the collimator arrangement being provided for varying an exposure areas of said registering means (43) to x-ray radiation from said x-ray source (10), a method for providing said variable exposure of said registering means
characterised by
providing said collimator arrangement with at least two substantially similar collimator parts (42a, 52a; 42b, 52b) having similar slot configurations and arranging said parts on top of each

other displaceable relative each other.

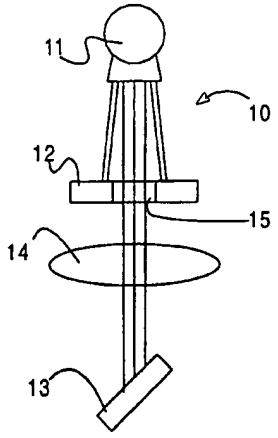


Fig. 1

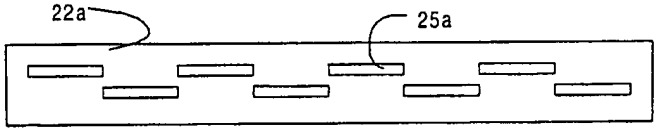


Fig. 2a

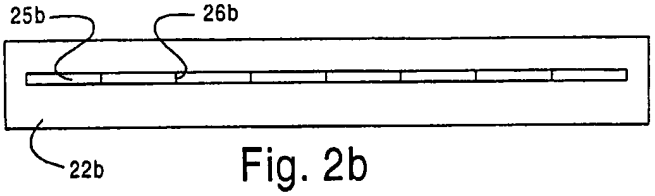


Fig. 2b

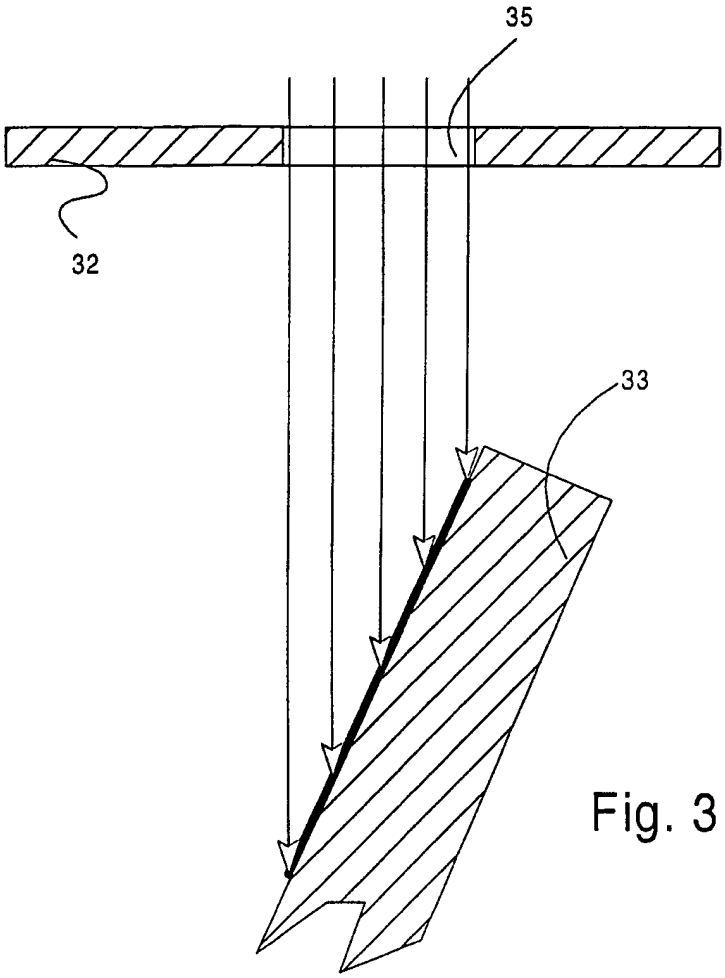


Fig. 3

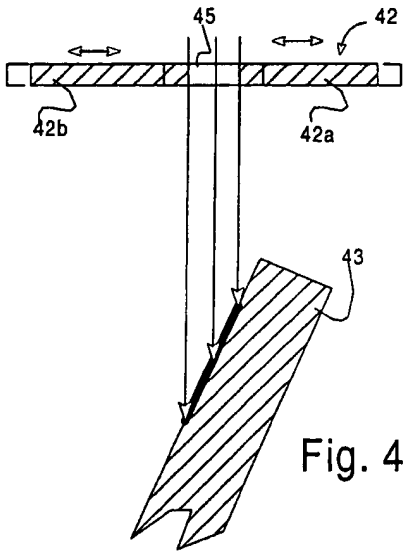


Fig. 4

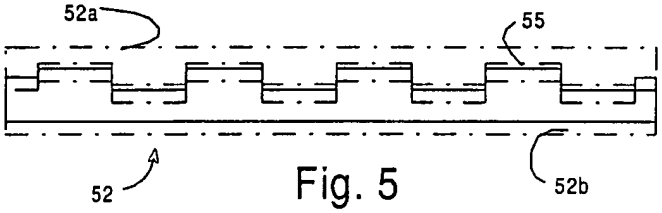


Fig. 5

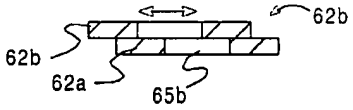
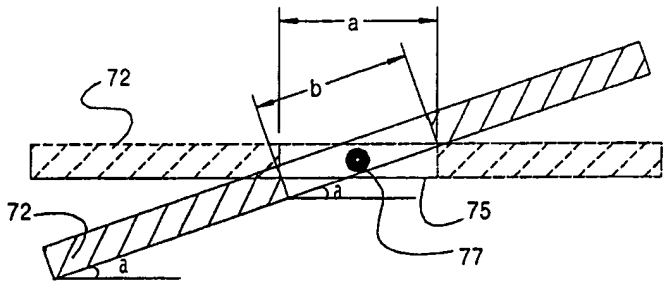


Fig. 6



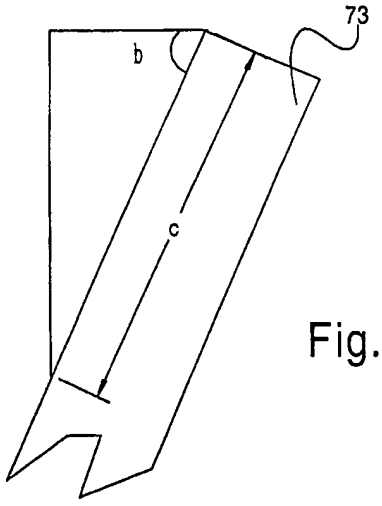


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/00139

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G21K 1/04
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G21K, H05G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4143273 A (RICHEY ET AL.), 6 March 1979 (06.03.79), column 2, line 45 - column 3, line 9, figures 1,12-16, abstract --	1-5
A	US 4778997 A (DÖRING), 18 October 1988 (18.10.88), column 5, line 3 - line 68, figure 4, abstract --	1-5
A	US 4953189 A (WANG), 28 August 1990 (28.08.90), column 6, line 28 - line 31, figures 4,6,7, abstract --	1-5

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 May 2001	21 -05- 2001
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Cilla Lyckman /OGU Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 01/00139

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5136627 A (CONRADS ET AL), 4 August 1992 (04.08.92), figure 2, abstract -- --------	1-5

Form PCT/ISA/210 (continuation of second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/04/01

International application No.
PCT/SE 01/00139

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